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Vacuum Forming Safety and Basic Use

COURSE # FAB105

Version 2.4

2x2
1x1
5"x5"

Course Synopsis

In this Safety and Basic Use (SBU), class you will learn the principles and practices of vacuum forming shapes from plastic sheet material to make three-dimensional parts and molds.

Time Required: 2 hours

Tools Required

- ☐ Vacuum forming machine (Formech 686)
- ☐ Air gun and hose
- ☐ Band saw, scroll saw, Dremel or other cutoff tools to trim parts
- ☐ Belt sander, disc sander or sand paper to finish edges of trimmed parts
- ☐ Cotton rags to wipe down plastic and plug form
- ☐ Brillianize plastic cleaner, eliminates static for less dust attraction
- ☐ Buffer to polish Styrene sheets prior to forming

Materials Required

- ☐ Plastic for vacuum forming – styrene, ABS and PETG are common types
- ☐ Structural foam to create a mold from

TechShop Safety Policy

- Closed toe shoes must be worn at all times in TechShop
- Do not use tools or equipment while tired, distracted or under the influence of drugs or alcohol
- If a tool is damaged or missing parts, notify TechShop staff immediately
- Never leave a machine running unattended
- Do not force equipment or tools; ask a TechShop staff member for assistance if you encounter any difficulties in operation
- Ensure equipment is safely OFF before walking away

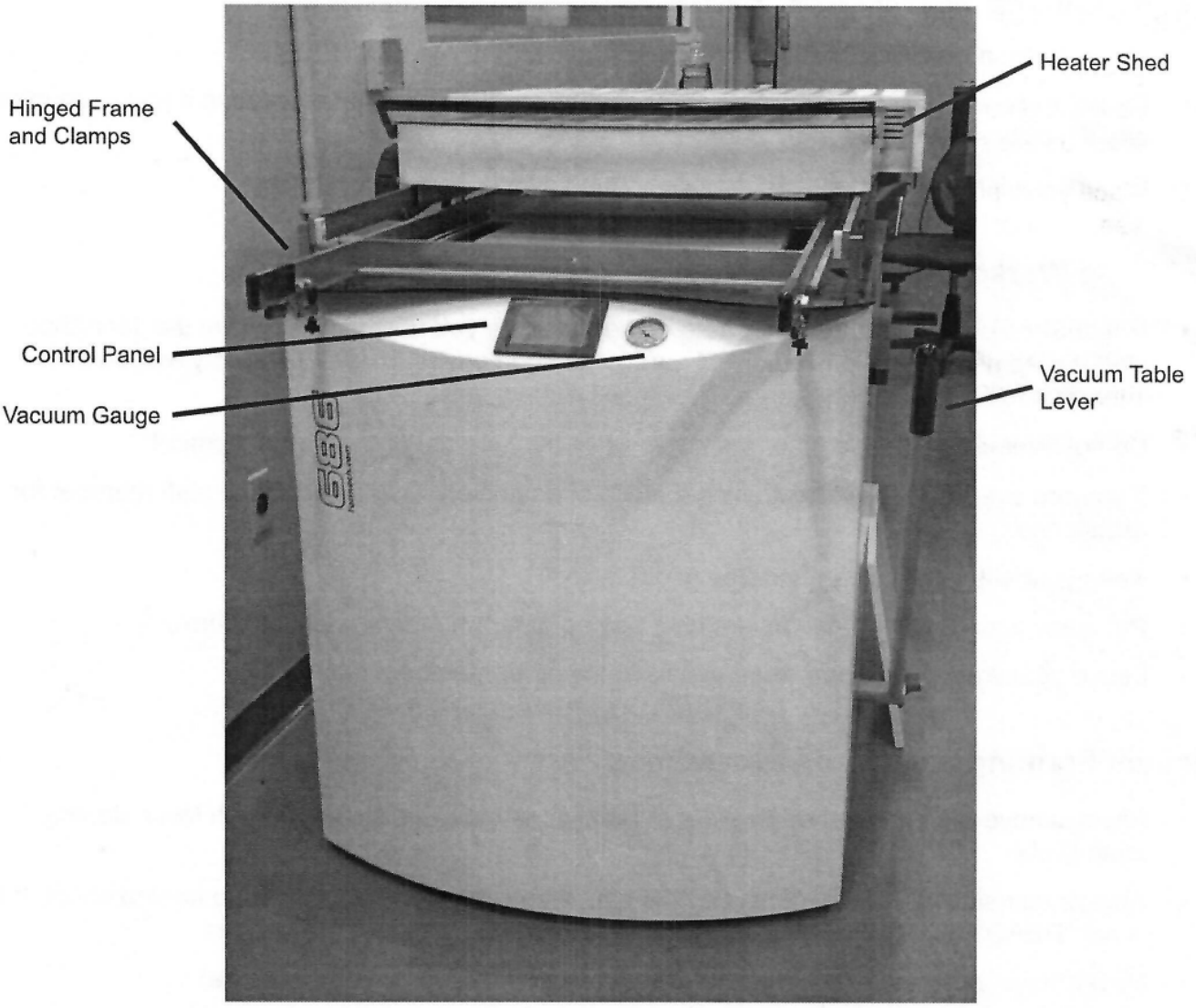
TechShop Workspace Etiquette

- If TechShop equipment breaks or gets damaged while you are using it, inform the TechShop staff. Equipment damage is a normal part of the shop environment – for safety reasons it is important to inform a TechShop staff member immediately
- Do not attempt to engage other members while they are using tools or equipment
- If you are ever uncertain about using a piece of equipment, ask a TechShop staff member for assistance
- Keep your work area clean and free of obstacles
- Put away your tools and equipment after use so other members may use them
- Leave your work area clean when you finish so other members may use it

Vacuum Forming Safety and Procedures

- Always move the heater shed away from mold-zone before raising mold with lever starting mold cycle
- Always test-sight heated material BEFORE moving plug or mold cavity up to heated sheet. If it is not "READY," you will risk machine damage, plug damage and a failed part
- Never leave vacuum forming heaters on and unattended (e.g., in RUN mode)

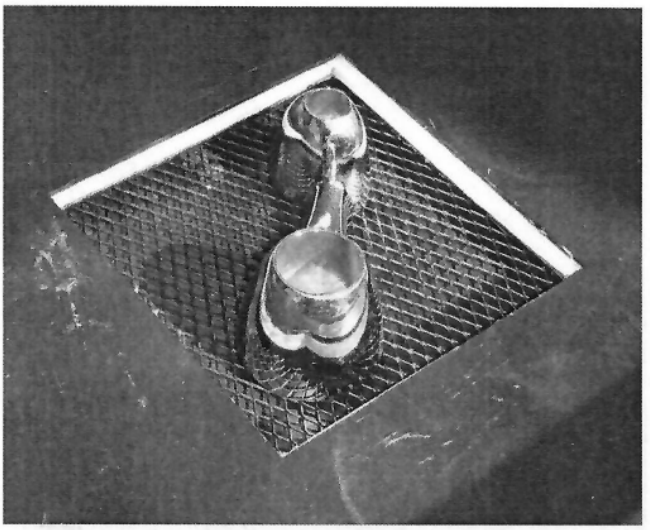
Anatomy of the Vacuum Forming Machine



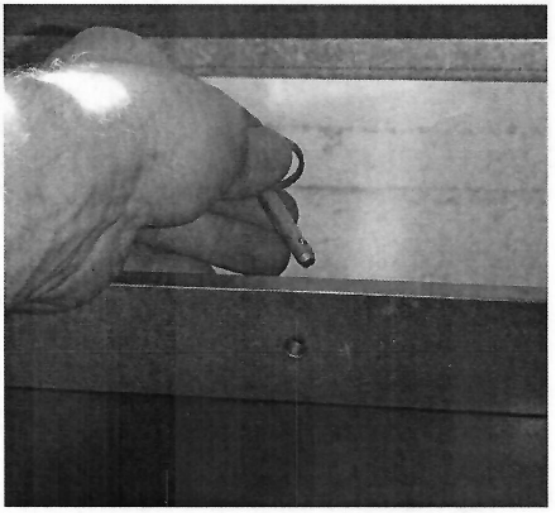
Overview

The vacuum forming machine heats a thin sheet of plastic until it is very pliable, then stretches it over a mold and sucks the air out from between the mold and the plastic, forming the plastic to the mold.

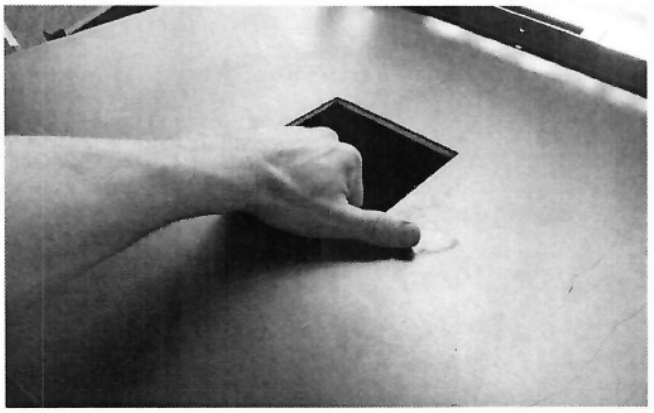
Setup



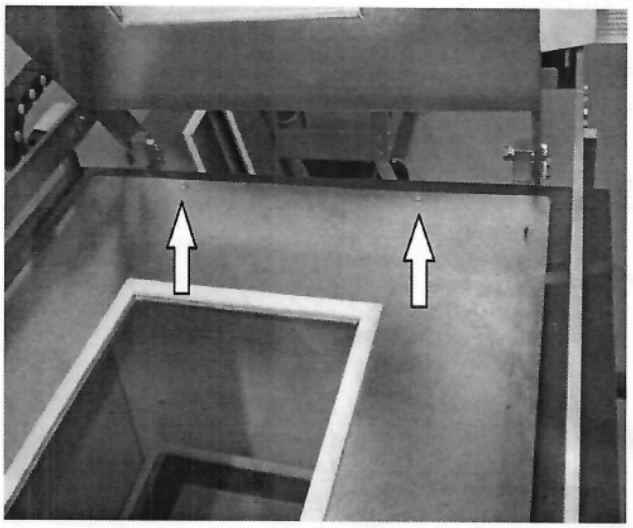
1. Start by raising the vacuum table as high as it will go by pulling the vacuum table lever on the side of the machine.
2. Place your mold on the vacuum table to see whether the aperture plate is correctly sized for the mold. Generally, it's good to have 1 to 2 inches between the mold and the edges of the aperture opening. Flatter molds may need less, while taller molds may need more.
3. Push the vacuum table lever on the side of the machine away from you to lower the vacuum table. The mold should be several inches below the aperture plates to avoid being heated too much when the plastic is heated.

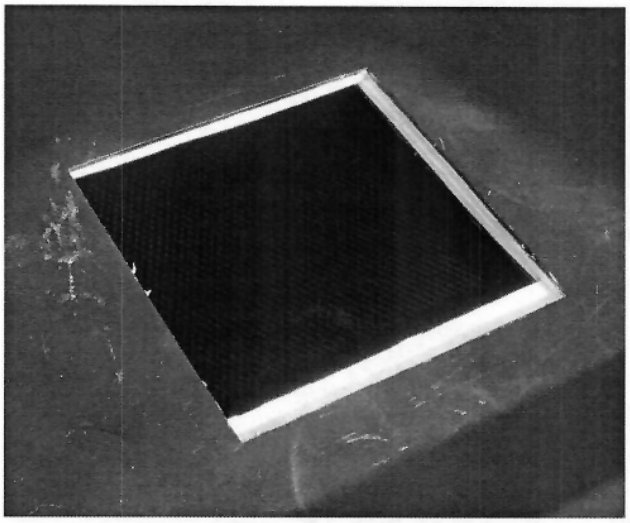


4. To change aperture plates, start by removing the upper aperture plate. Hold the hinged frame down and pull the pin out nearest to you. Keep holding the frame down while you pull out the rear pin out, then gently let the hinged frame up until it stops.
5. Lift the aperture plates by holding them in the center. Keep the seals in good condition by never sliding them against each other or another surface. It's easy to lift one end of the aperture plate to get a hand hold in the center.

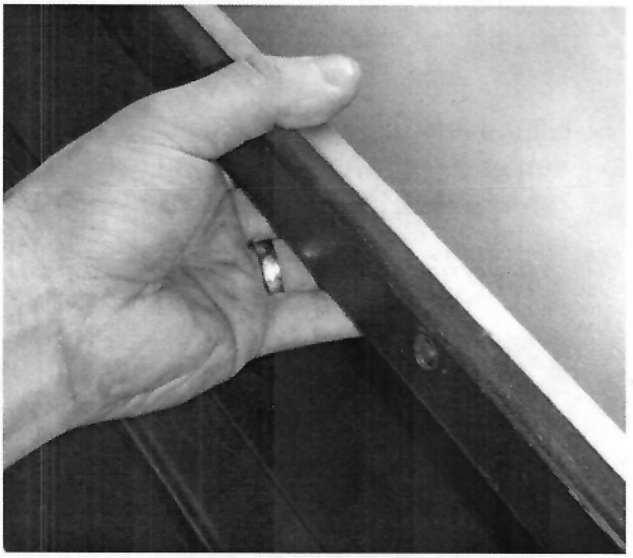


6. The lower aperture plate has two pins that it registers on. Carefully remove the plate to avoid damaging it or the pins.
7. Install the new aperture plates, starting with the bottom plate. Slide the plate over the register pins carefully to ensure the plate is properly centered in the machine.





8. Place the upper aperture plate on the lower plate, offset about 1/2 inch to the rear of the machine and centered over the lower aperture opening. Lower the hinged frame down and work the rear pin into place.
9. Hold the frame down and lift the front of the aperture plate up to move it all the way to the front of the machine. Line the holes up in the plate and frame, and insert the second pin.

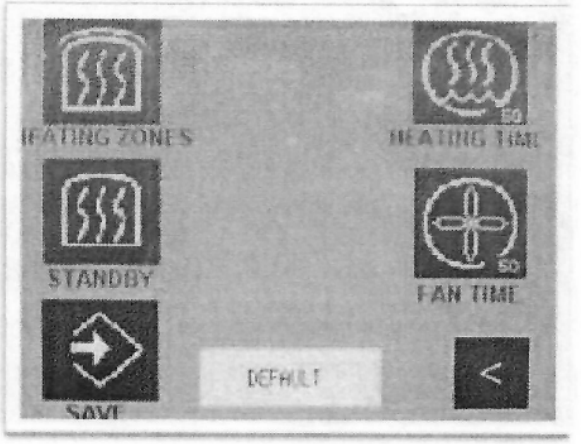


10. Raise the vacuum table to check the clearances between the mold and aperture plates, then lower it back down several inches below the aperture plates.
11. Now that you know how large your aperture will be, you can set up the heater elements. Turn the machine ON with the large switch in the back of the machine.

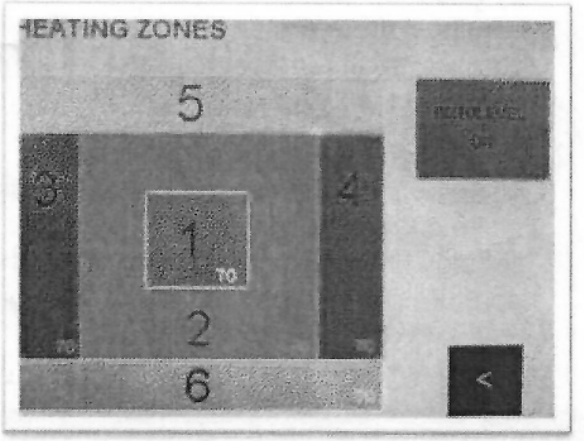
Programming and Edit Menu Functions

When the machine boots up, it loads the default program, which probably isn't the program you'll want to use. To change the program, press New/Edit.

The Edit menu functions are used to control the machine.



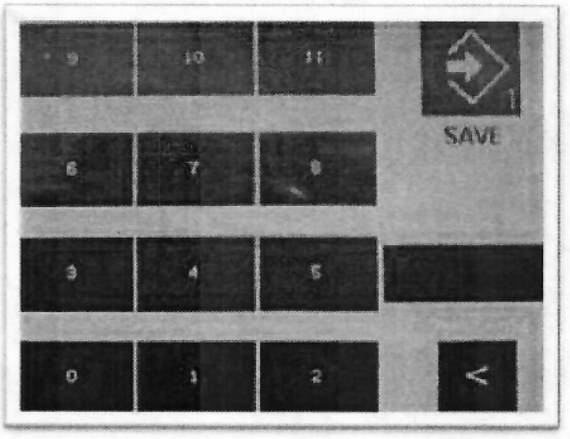
Heating Zones allows you to select which heater elements to use, as well as how hot to make them. Set up the zones based on your aperture size and location. Heat is not temperature based but uses a percentage of heater power. Cooler forming materials use a lower percentage, while hotter forming materials use a higher percentage. Since a lot of plastic gives off noxious fumes when overheated, it's best to start with lower temperatures and work your way up.



Standby Temperature allows you to set the temperature of the heaters when the heater shed is not over the plastic to be formed. Standby temperatures default to 50% of the Heating Zone setting, and the machine quickly ramps up to the specified Heating Zone settings when over the plastic.

Heating Time is timer that activates once the heater shed is pulled over the plastic to be formed. If you're forming a lot of parts, the timer can be a real boon, but it will take several cycles to set up the right time. On the first couple of parts, watch the droop of the plastic and adjust your heat or time accordingly.

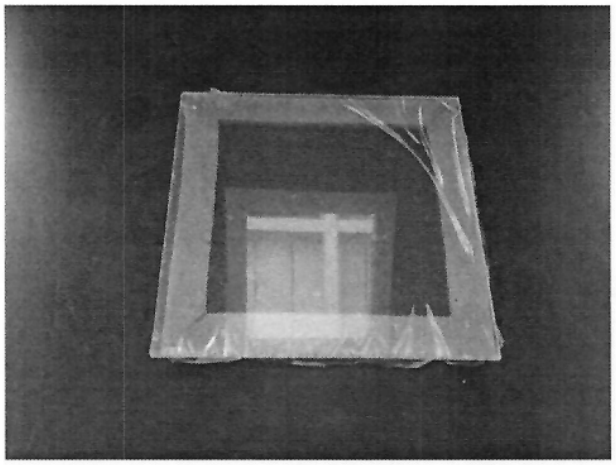
Fan Time controls how long a fan will blow on your parts to cool them down after the heater shed is pushed back and the parts are formed.

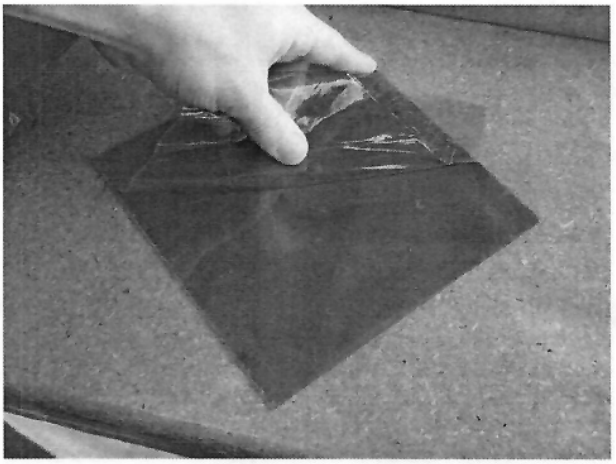


Once your settings are the way you'd like, use the Save button to save them to one of the 11 program slots in the machine. Name your program by pressing the black rectangle on the right side of the screen.

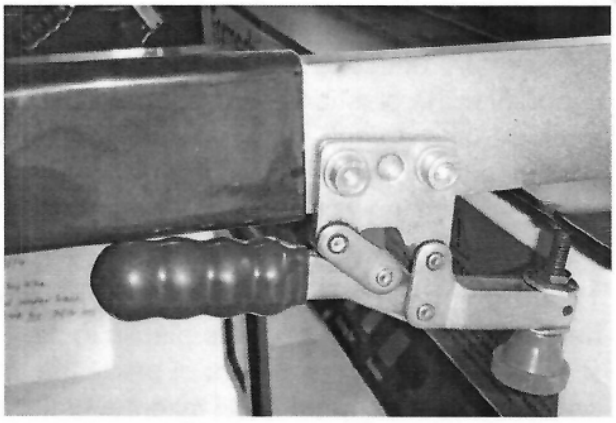
Basic Operation

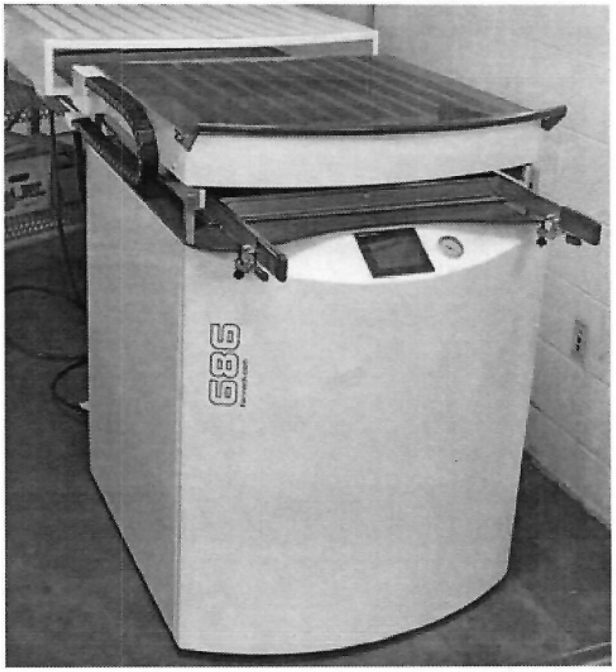
Once the machine is set up, place your desired material in the aperture opening.





1. The material should overlap the opening by about an inch in each direction for best results. If there are any protective films on your material, remove them before applying heat.
2. Lower the upper aperture plate down and clamp it in place. The clamp should make a thump when clamped in place, but shouldn't take two hands to squeeze the aperture plates together. Adjust the clamping pressure by loosening the plastic knob and making the bolt shorter or longer. Shorter decreases clamping pressure, while longer increases it.

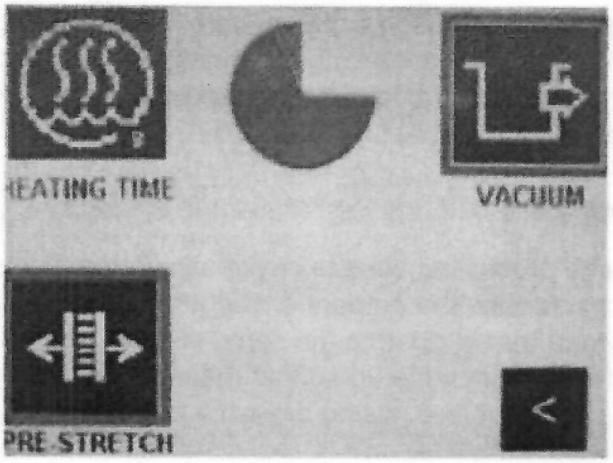


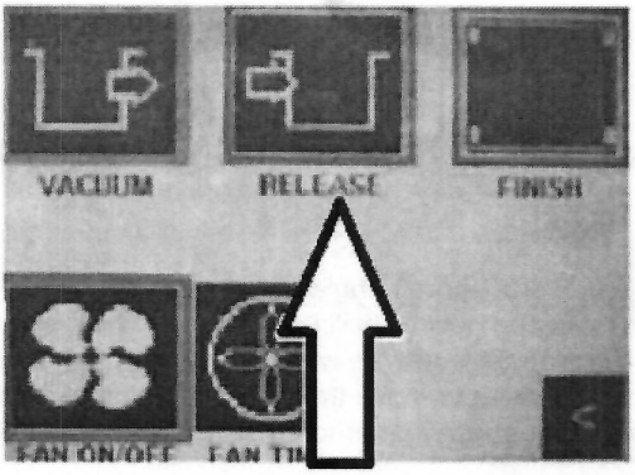


3. The heaters take between 20 and 30 minutes to heat up. Once they are hot, slide the heater shed over the plastic. Pull the shed towards you as far as it will go to start the timer.
4. If you are still testing how long to heat the plastic, observe how the plastic is heating and drooping. Start Zone 1 at 40% and Zone 2 at 50% for smaller frames. For larger frames, the additional heaters should be set at equal percentages. The appropriate amount of droop depends on how big the plastic is and how tall your mold is. Bigger sheets or taller molds

require more droop. Make a note of how much time it takes and adjust the heating timer accordingly.

5. Once the plastic has heated up, push the heater shed back, pull the vacuum table lever, slowly, to raise your mold, and then press the Vacuum button to remove the air inside the machine and form the plastic to the mold.
6. After the plastic has solidified and cooled enough that you can touch it without burning yourself (generally, 20 - 30 seconds), push and hold the Release button to apply pressure from underneath to help release the mold from the plastic.





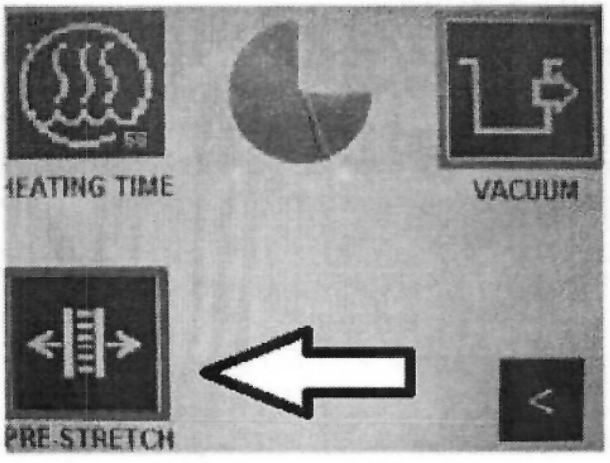
7. Unclamp the apertures and pull the formed part out. You may need to use a little compressed air to pop the mold out of the plastic.
8. Reload the vacuum former with a new sheet of plastic and repeat the operation.

Special Operations and Techniques

Operations

Self Level Mode uses a light beam underneath the aperture to detect plastic droop. If the plastic droops and breaks the beam, the machine shoots a puff of air to the underside of the plastic to help eliminate the droop.

Pre-stretch is handy when using tall molds. After the plastic is hot and the heater shed is pushed back, use pre-stretch to apply pressure underneath the plastic to stretch the plastic up. This will help achieve a more even wall thickness when the plastic must stretch a lot to cover the mold.



Techniques

When forming molds, there are a couple of helpful techniques to avoid webbing around male molds or material becoming too thin in cavities.

Web Prevention

To prevent webbing, raise the vacuum table to an inch below the apertures, push the plastic down to the mold with something smooth, then raise the vacuum table the rest of the way and apply vacuum. By forming the plastic to the mold before applying vacuum, you can avoid creating webs of plastic around your mold.

Cavities

The same process applies to cavities in your mold where the material may stretch too far and create holes that reduce the amount of vacuum applied to form your parts. Find an object (wood dowels work great) that is close to the same size as the cavity you're trying to fill. When the plastic is hot, bring the vacuum table up so that the entrance to the cavity is touching the plastic, push the plastic into the cavity before raising the table fully and applying vacuum.

The Mold

Mold Design

When designing molds, there are a few things to keep in mind.

Taper the Mold

One of the most important things is to incorporate some sort of draft angle into the design. When the plastic cools down, it also shrinks. With straight walls up and down, it will be difficult, if not impossible, to remove the mold from the plastic because of the friction between the walls and plastic. However, if you taper the mold as it reaches the top, then you only need to move the mold a fraction of an inch before the walls are not in contact with the part. The taper doesn't need to be very much – figure 3 - 5 degrees for male molds and 1 - 4 degrees for female cavities.

Support the Mold

Another problem is undercuts, which occur when the mold is smaller on the bottom than on the top. If the mold is slightly flexible, you may be able to work it out of the part, but a rigid mold may well become trapped in the part you mold to it. Balled up aluminum foil or fabric are good ways to add support a mold that has undercut areas.

Mold Materials

Molds can be made from a wide range of materials. Wood and high density foam are both great choices and easy to form. If you are using clear plastic to form and need a smooth finish, be sure to use a material than can provide a very smooth finish, since even small surface roughness will show up in the finished product. Mold materials do not have to be super heat resistant, but they should be capable of being heated to 200° F without deforming.

Plastic Materials

There are a wide range of plastics available to use with the vacuum forming machine.

Most plastics are hygroscopic, which means they will absorb moisture out of the air. If bubbles are a problem in the final product then you will have to dry the plastic in an oven before forming it. The plastic supplier should have times and temperatures used based off material and thickness.

Some plastics form and machine better than others. All plastics will shrink a certain amount. If you're making precision parts, you'll need to account for that in your mold. For a description of properties of many plastics, see the list in the Plastic Material Properties section

Thickness / Heat Timer Suggested Settings

The following timer settings guide assumes the Heater Shed (for zones used) has warmed for at least 20-30 minutes. NOTE: Ambient room temperatures will affect the actual time needed.

When heating thicker plastics, keep in mind that the *heater settings* stay the same as thinner plastic, but the *time* spent heating the plastic increases incrementally. If it takes 60 seconds to properly heat .040" material, then it will take roughly 120 seconds to heat .080" material at the same heater settings.

It is possible to heat 1/4" (.250") thick plastic in the machine but heating times will be very long.

Plastic Type	Thickness	.040"/1mm	.060"/1.5mm	.093"/2mm	.125"/3mm	.177"/4mm
	Polystyrene	30	45	60	90	120
	ABS	40	60	80	120	160
	Polypropolene	50	75	100	150	200
	Polyethylene	50	75	100	150	200
	PETG	30	45	60	90	120
	PVC	30	45	60	90	120
	Polycarbonate	60	90	120	180	240

Heating Time Start Point in Seconds

Plastic Material Properties

ABS (Acrylonitrile Butadiene Styrene)
Hard, rigid, amorphous thermoplastic with good impact strength and weather resistance. It contains a rubber content which gives it an improved impact resistance. Available with different textures and finishes in a range of thickness as well as fire retardant and UV stabilized grades. Hygroscopic. Easily forms to a high definition. High strength. .3% - .8% shrinkage rate. Machines well with a variety of tools.

Acrylic (PMMA, Perspex, Lucite, Plexiglas)
A high quality, hard, amorphous plastic with good clarity that can be worked after forming. Note: Only extruded sheet is suitable for vacuum forming effectively. Cast acrylic will not respond well as it displays a very small usable plastic zone. As a result, it will only produce general contours

with large drape radii. Often replaced by PETG. Hygroscopic. Tends to be brittle and temperature sensitive when forming. Medium to high strength. .3% - .8% shrinkage rate. Prone to shattering when machining.

Co-Polyester (PETG / VIVAK)
An easy forming, amorphous thermoplastic. FDA approved for food applications. Optically very good with excellent fabricating performance. Thermoforms with ease utilizing low temperatures and fast cycle times. Can be sterilized and is resilient to a wide range of acid oils and alcohols. Not recommended for use with highly alkaline solutions. Hygroscopic but predrying only required when plastic is exposed to high humidity for an extended amount of time. Easily forms to a high definition. Good strength with high impact strength. .3% - .5% shrinkage rate. Machines well with a variety of tools.

Polystyrene (Polyphenylethene, High Impact Styrene, HIS, HIPS)
One of the most widely used materials. An easy forming, amorphous thermoplastic. Thermoforms with ease utilizing low temperatures and fast cycle times. Available with different textures and patterns. Poor UV resistance – not suitable for outdoor applications. Not hygroscopic. Very good formability to a high definition. Medium to high impact strength. Machines well with a variety of tools.

Polycarbonate (PC, LEXAN, MAKROLON)
Hard, rigid, clear amorphous plastic with high impact resistance and good fire rating. Self extinguishing. Excellent clarity. Similar properties to acrylic. Hygroscopic. Good formability but requires high forming temperatures. Very good impact strength. .6% - .8% shrinkage rate. Machines well with a variety of tools.

Polypropylene (PP)
PP is a semi-crystalline thermoplastic which has difficult form characteristics with sheet sag inevitable. Chemically inert and very flexible with minimum moisture absorption makes it suitable for a wide range of applications. Many grades of PP are available containing fillers and additives. Copolymer as opposed to homopolymer PP is recommended for vacuum forming, as the copolymerization process helps reduce stiffness and broaden the melt and glass transition temperatures, increasing thermoforming ability. Not hygroscopic. Difficult to form. Requires high temperatures and good temperature control as the forming temperature band is only about 10° C. Very good impact strength. 1.5% - 2.2% shrinkage rate. Machines well with a variety of tools.

Shutdown and Cleanup

1. Write down any settings you would like to keep for future vacuum forming operations, since the programmed settings will be lost once main power is turned off.
2. Turn the machine OFF using the large main switch in the back of the machine.
3. Leave the clamping frame open to avoid collapsing the seals.

Resources

www.tapplastics.com
The fantastic plastics place with a large supply of plastic, as well as tips and how-tos. Stores in California, Oregon and Washington. Shipping is available.

www.professionalplastics.com
Hundreds of plastics for sale.

www.sabicpolymershapes.com
Full service distributor of plastic materials and related products. Ships to the U.S. and internationally.

What's Next?

After successfully completing this Vacuum Forming Safety and Basic Use class, you might be interested in these classes:

CNC302: CNC ShopBot SBU
Create a mold using the ShopBot CNC router system from a CAD file.

PRO102: MakerBot Replicator 3D Printer
3D print your own mold using the MakerBot 3D printer.

NOTE: Not all classes are available at all locations. Check online (www.techshop.com) or visit your local TechShop for a complete list of class offerings near you.

The Fine Print